Pressure head or head $\stackrel{\text{def}}{=} \dfrac{p}{\rho g}$

Ex:

pressure = 101325 Pa

Water head (SG = 1) $= \dfrac{101325}{(1000)(9.81)} = 10.33 \text{ m}$

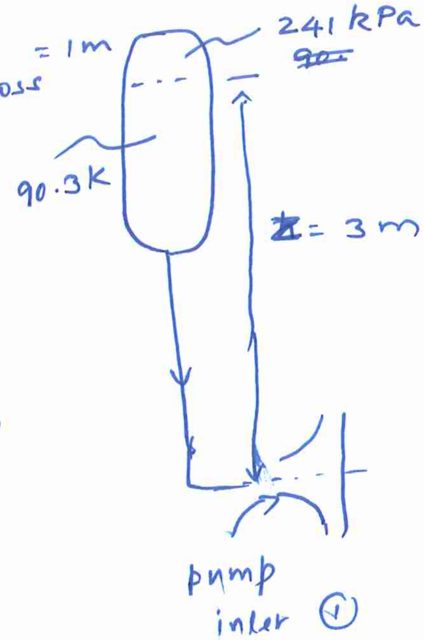
Mercury head (SG = 13.6) $= \dfrac{101325}{(13600)(9.81)} = 0.76 \text{ m} = 760 \text{ mm}$

Lox head (SG = 1.140) $= \dfrac{101325}{(1140)(9.81)} = 9.06 \text{ m}$

A pump becomes susceptible to cavitation if the fluid pressure is less than its vapor pressure.

Ex

$\dot{m}_{LOX} = 182\ kg/s, \quad \rho_{LOX} = 1140\ kg/m^3, \quad z_{loss} = 1m$



$D_1 = 11\ cm$

$p_{01} = p_{tank} + \rho g h - \rho g h_{loss}$

$z_{01} = z_{tank} + z - z_{loss}$

$z_{tank} = \dfrac{p_{tank}}{\rho_{LOX}\, g} = \dfrac{(241)(1000)}{(1140)(9.81)} = 21.55\ m$

$z_{01} = 21.55 + 3 - 1 = 23.55\ m$

$p_v = 1013\ mbar = 101300\ Pa$ @ $90.3\ K$ [LOX]

$z_v = \dfrac{p_v}{\rho_{LOX}\, g} = \dfrac{101300}{(1140)(9.81)} = 9.06\ m$

$p_1 = p_{01} - \rho_{LOX} \dfrac{u_1^2}{2}$

$A_1 = (\pi D_1^2/4) = 0.009503\ m^2$

$u_1 = \dfrac{\dot{m}}{\rho_{LOX} A_1} = \dfrac{182}{(1140)(0.09503)} = 16.8\ m/s$

$p_1 = p_{01} - \rho_{LOX} \dfrac{u_1^2}{2}$

$z_1 = \dfrac{p_{01}}{\rho_{LOX}\, g} - \cancel{\rho_{LOX}} \dfrac{u_1^2}{2} \cdot \dfrac{1}{\cancel{\rho_{LOX}}\, g} = z_{01} - \dfrac{u_1^2}{2g}$

$= 23.55 - \dfrac{16.8^2}{2(9.81)} = 9.16\ m$

$z_1 > z_v$, no cavitation

vapor does not necessarily form when p falls below p_v. A pure liquid can have p well below p_v without appearance of bubbles. It is impossible to remove all microbubbles and dissolved air (that may ~~seer~~ serve as nucleation sites). Turbulence and unsteady effects influence cavitation. Thus the inception of cavitation is inferred from experiments.

Cavitation is a significant limitation on pump performance. This phenomenon describes the formation of vapor bubbles in regions where the fluid static pressure declines to levels below the fluid's vapor pressure. Excessive bubble formation causes the flow rate to significantly decline. Also, the collapse of these bubbles as they reach higher pressure regions results in erosion of pump surfaces. Of the two, the latter is not considered a serious problem in rocket engines owing to their short duration of operation. In reusable engines (such as the SSME), however, the erosion effect does become important.

The variable $(P_{01} - P_v)$ is significant in analysis of cavitation. The associated head is known as the net positive suction head (NPSH).

$$NPSH \equiv \frac{P_{01} - P_v}{\rho g_0}$$

Here, P_{01} is the stagnation pressure of the fluid at the entrance to the pump (known as suction side) and P_v is the fluid vapor pressure.

The suction of the pump causes fluid to accelerate into it, and fall in pressure. If the acceleration is large enough, the static pressure reaches the vapor pressure value and cavitation becomes likely. As it happens, some cavitation is acceptable and performance problems arise only with excessive cavitation. Experiments show that a value for NPSH exists below which pump head declines dramatically. This value is called the required suction head [$(NPSH)_R$] and is dependent on the fluid of interest. Thus, to avoid cavitation-related performance problems, the available NPSH [$(NPSH)_A$] should be kept more than that required [$(NPSH)_R$].

Hill and Peterson,
"Mechanics and Thermodynamics of Propulsion."

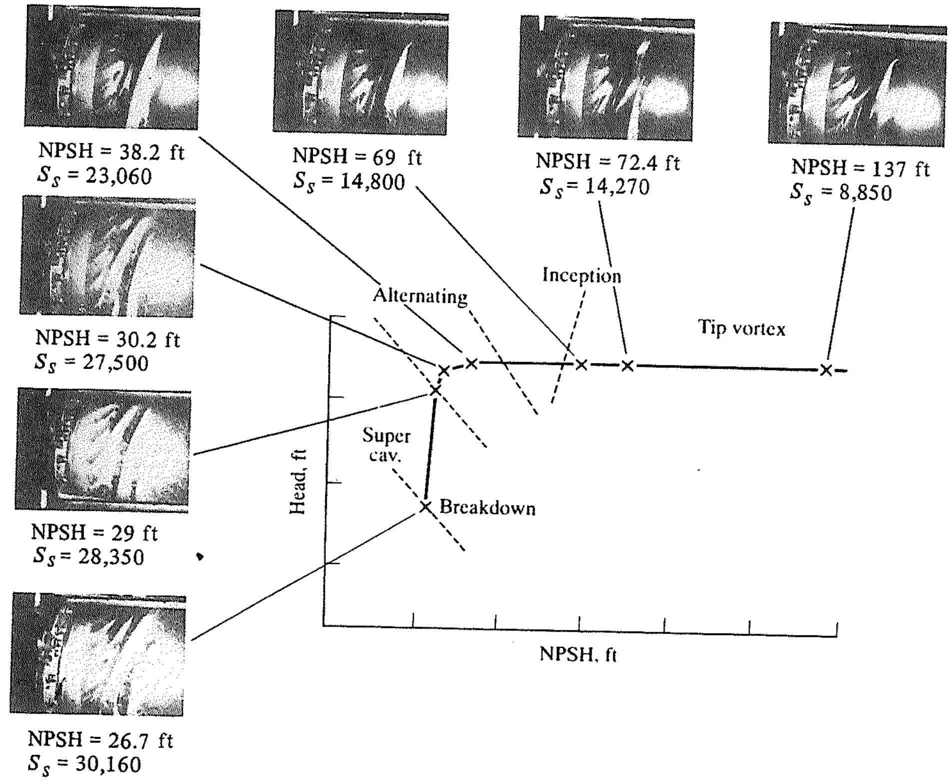


FIGURE 13.15 Experimental inducer cavitation characteristics. (Courtesy Rockwell International, Rocketdyne Division.)